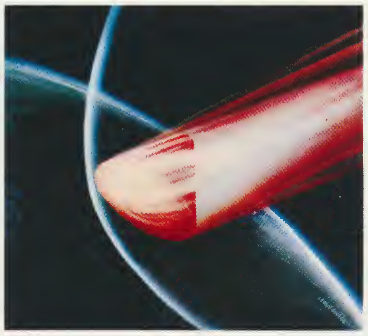


As U. S. astronauts re-enter the earth's atmosphere on their return from the moon, temperatures outside their Apollo vehicle will be near a mark of 5,000 degrees F.

Dow Products . . . AIDS TO AEROSPACE

By William B. Seward

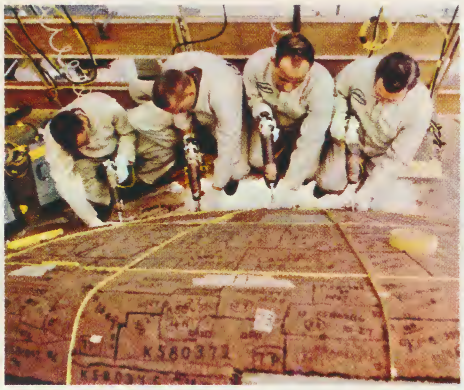
PLUNGING TOWARD THE EARTH at 25,000 miles an hour with the temperature soaring to 5,000 degrees F. That's what faces the Apollo spacecraft when American astronauts return from the moon. The Apollo spacecraft will be enveloped in white flame.

This will mark one of the most dramatic performances in space by a product of The Dow Chemical Company. The basic material in the Apollo ablative heat shield is a unique epoxy resin developed and manufactured by Dow. Scientifically it is known as an epoxy novolac and is trademarked D.E.N. 438.

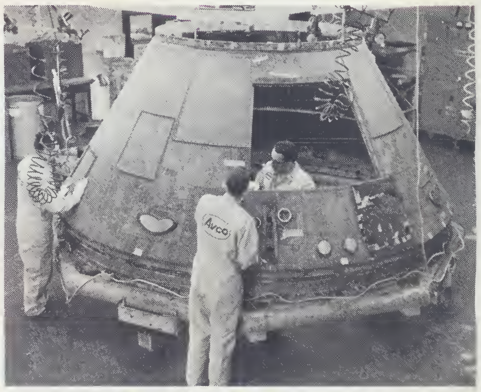
Like most materials, D.E.N. 438 epoxy novolac cannot withstand 5,000-degree temperatures. But as formulated and fabricated on the spacecraft by Avco Corporation, the heat shield chars as it burns—something like the burning of a wood log—and the spacecraft and astronauts are protected.

In essence, an ablative material is simply one that dissipates heat by burning. On a space mission, it keeps burning until reduced speed has eliminated the heating problem.

An important characteristic of Avco's epoxy-base ablative material is that it is a tremendous insulator. Encasing the entire spacecraft, it will keep the stainless steel frame from getting hotter than 600 degrees F. even though the shield is only one and a half to three inches thick.



Injected into each honeycomb cell is an ablative material. Basis of the material is D.E.N. 438 epoxy novolac, produced by Dow. This is the blunt aft section of the craft.



The crew compartment, one of four sections of the Apollo module, is inspected by Avco/RAD engineers. A honeycomb matrix of glass fiber will now be bonded to each section.

D.E.N. 438 resin, the first epoxy novolac, was developed before scientists had delved deeply into the problem of how to safely re-enter the earth's atmosphere. Avco's Research and Development Division at Wilmington, Massachusetts, was organized specifically to help develop re-entry vehicles for intercontinental ballistic missiles. Avco/RAD's work on spacecraft heat shields is an outgrowth of that experience.

Fabrication of the Apollo heat shield starts with a glass fiber honeycomb shaped to fit the spacecraft and machined to precise dimensions. This is bonded to the stainless steel frame—with an adhesive based on another Dow epoxy resin.

The ablative material is injected into each of more than 370,000 cells. Curing, or hardening, of the material is done in huge ovens at 350 degrees F.

Eventually, after many steps of X-ray and dimensional inspection, it is painted with a white, reflective paint.

The ablative heat shields first used on missiles were metal and, by comparison, they were monstrously heavy. In the Apollo heat shield, additional weight is saved, and the insulating properties are

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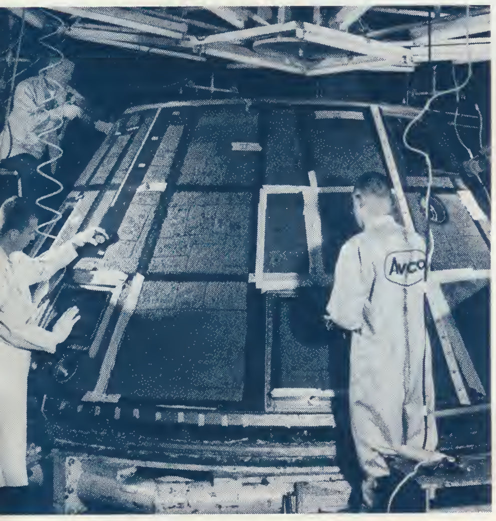
Special injection guns, containing heating elements, were developed to inject the ablative material. Every inch of the sections is then X-rayed. Severe conditions which Apollo will face make it necessary to cover the entire module with ablative material.



improved, by mixing the epoxy resin with silica fibers and a powdery plastic substance known as Microballoon spheres.

"We never have deviated from D.E.N. 438 in our work on Apollo ablative heat shields," says Dr. Coy L. Huffine, Avco/RAD project manager for heat shield manufacturing. "We have found it is much superior to other materials in the stability of its charring. When it burns and chars, it doesn't fly off in chunks. Instead it sticks together tenaciously."

Avco/RAD's development of the Apollo heat shield required consideration of conditions more severe than those faced in Project Gemini. For instance:

—Temperatures of 5,000 degrees F. compared with 3,000 degrees F.

—Re-entry speed of 25,000 miles an hour instead of 17,500, requiring a two-phase descent with an intermediate leveling-off stage. Without the pause, the astronauts couldn't survive the rapid deceleration.

—Exposure to the extremely high temperatures for 20 minutes, instead of eight or nine.

—The necessity for encasing the entire command module in ablator, rather than just the blunt aft end. Even the pointed tip will encounter temperatures near 4,000 degrees F., and the quartz-glass windows will be blackened within seconds.

Although developed primarily for less spectacular applications, D.E.N. 438 is meeting a critical need in the space program. At the same time, other resins in Dow's versatile family of epoxies are performing in a wide variety of space applications.

D.E.R. 332 curing agent is used by United Technology Center for the binder in the solid propellant in the strap-on booster motors of the Titan 3-C rocket. D.E.R. 332 and D.E.R. 331 perform the same function in the huge, solid-propellant rockets developed by Thiokol Chemical Corporation and Aerojet-General Corporation, and also in Minuteman missiles.

Epoxy coatings formulated with Dow resins by International Epoxy Corporation are used in painting missile structures at Cape Kennedy. Also at the Cape, Dow epoxies are used in nonskid surfaces for the escape tunnels in launch complexes.

At Launch Complex 39, now being built for the Apollo/Saturn V missions, firebricks in the flame trench are adhered to concrete walls with an epoxy mortar produced by Protective Coatings, Inc. A thin layer—only 0.015 inch—of mortar holds the bricks in place despite the pulsating vibrations at lift-off.

International Epoxy, headquartered at Fort Lauderdale, Florida, and Protective Coatings, Tampa, Florida, both are companies that have grown substantially as a result of the construction boom at Cape Kennedy.

While epoxies are meeting a variety of requirements in the space program, other Dow plastic, metal and chemical products also are used extensively.

The missile or spacecraft built without Dow magnesium is a very rare bird. The basic Agena vehicle contains more than 600 pounds of magnesium sheet, extrusion, forging and castings. Telstar, the first communications satellite, was mostly magnesium.

The adapter section of the Gemini spacecraft is about 85 per cent magnesium. In Gemini and many other space applications, the magnesium contains small amounts of thorium in alloys developed by Dow for higher strength at elevated temperatures.

The Titan, Polaris, Vanguard, Jupiter and Scout vehicles all were lighter because of magnesium; the same is true for the Agena, Echo, Courier, Early Bird and a number of other satellites.

Probably the most dramatic space performance of magnesium was in the successful launching of Mariner 4. This vehicle's 325-million-mile interplanetary trip to shoot pictures of Mars began 23 days after the failure of Mariner 3.

The difference between Mariners 3 and 4 was the substitution of a magnesium shroud for a fiberglass unit. The shroud was designed to protect the vehicle during its escape from the atmosphere, but on Mariner 3 gas trapped in the fiberglass honeycomb cells overheated and caused the skin to "delaminate."

At Lockheed Missiles and Space

The versatile family of Dow epoxies includes D.E.R. 331 and D.E.R. 332 curing agents used for binders in a number of solid propellants such as the one under test here by Thiokol.

Company, 560 engineers and government employees compressed into 10 days the job of fabricating a magnesium shroud. On November 28, 1964, Mariner 4 was launched just before the "window" to Mars closed. Otherwise it would have been necessary to wait until December, 1966. ("Window" is the time open when a satellite, planet, moon or other destination is in the correct position for launching to rendezvous, fly by, dock or make physical contact.)

Magnesium also played a prominent role earlier in the Mariner program. Mariner 2 was launched on a Venus probe after magnesium had replaced the aluminum that had been used in the Mariner A structure. Magnesium was substituted when it became necessary to cut the weight in half because of delays in the development of the Centaur rocket originally scheduled for launching the Mariner spacecraft.

Aluminum pipe extruded by Dow has been installed at Merritt Island for moving nitrogen gas. Approximately three miles of the pipe, 14 inches in diameter, parallel the road leading to the launch pad at Complex 39.

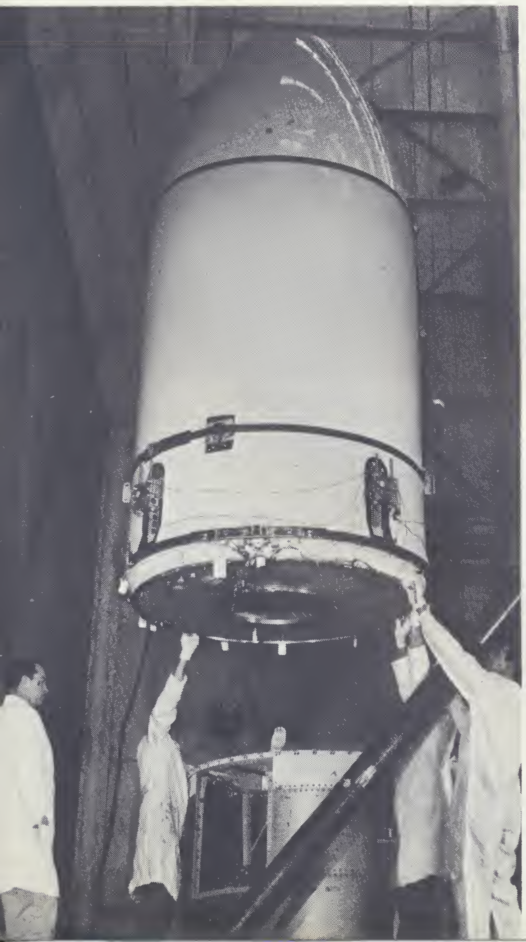
Meanwhile, Dow's plant at Madison, Illinois, has undertaken a big assignment for the military in producing miles of portable aluminum mats for landing aircraft in Vietnam and elsewhere. The current work is being done under a $5.5 million contract. Another big aluminum job assigned to Madison was production of 75-foot wing members for the Air Force's B-52H missile bomber.

As described in previous issues of the *Dow Diamond,* cesium is a Dow metal that may play major roles in future space travel. An ion engine using Dow cesium has been successfully tested in an orbit 700 miles from earth.

"It is believed that for certain space applications the ion engine with 100 pounds of cesium is equivalent in thrust to a conventional rocket carrying a ton of propellant," says Gordon Sohl, physicist for Electro-Optical Systems Inc. EOS developed the tiny, ion engine launched in an Air Force Agena vehicle last April.

Dow's newest operation in metals, Precision Fabrication Services, at Denver, Colorado, has developed about half of its business in the aerospace field since starting operations in 1964. PFS uses numerically controlled machining to produce space hardware, and parts for aircraft such as the F-111. Titanium, magnesium, aluminum and stainless steel are among the major metals handled by PFS.

Dorvon polystyrene foam played an unusual role in two of the most recent manned space flights. During the flights of both Gemini 5 and 7, the astronauts were asked to look for large white rectangles on the ground near Laredo, Texas. The rectangles were made up of 4,700 panels sur-

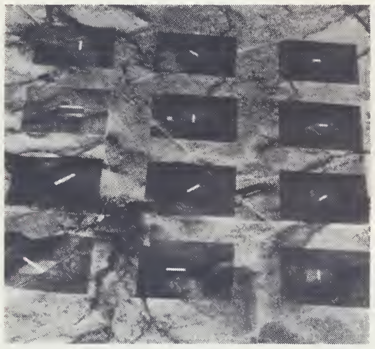


It is an absolute necessity that "space" systems be ultraclean. Specifically for "white room" use, Dow developed *Dowclene* WR. As world's leader in development and production of chlorinated solvents, Dow supplies much of that used in space work.

A magnesium shroud is placed on Mariner 4 at Lockheed Missiles and Space Company. The shroud was fabricated in just 10 days and was on a journey to Mars just 23 days after Mariner 3 failed, in late November, 1964, when trapped gas in the glass fiber honeycomb caused the skin to delaminate.

The huge, white rectangles which the astronauts of Gemini flights 5 and 7 were looking for near Laredo, Texas, were panels of *Dorvon* plastic foam produced by Dow. The plastic panels are shown here during installation.

This picture released by NASA shows how the rectangles of *Dorvon* looked from an aircraft. Three rectangles were correctly identified, by Gemini Astronaut Frank Borman, on one pass.



faced with the *Dorvon* plastic foam for controlled reflection of sunlight.

The question was whether an astronaut's vision is so improved in space he could make sightings equivalent to spotting a thimble from 50 yards. Astronaut Frank Borman reported that on one pass over Laredo he correctly identified three rectangles.

In a more conventional application, *Styrofoam* brand expanded polystyrene helps insulate several buildings at Cape Kennedy. *Ethafoam* polyethylene foam, with high flexibility, is used extensively as a protective cushion in shipping delicate missile and spacecraft components.

Dow is the world leader in the development and production of chlorinated solvents, so it is only natural that the company supplies a large share of the hundreds of thousands of gallons used in space work. Since space systems must be ultraclean, materials such as *Chlorothene NU* and *Dowclene WR* solvents are put to work all along the line from factories manufacturing tiny components to the launch complexes.

Dowtherm 209 heat-transfer agent is another product that performs a supporting function. At DEW (Distant Early Warning) bases near the Arctic Circle, *Dowtherm 209* serves as an ebullient coolant for diesel engines. It also has been used in diesel engines at missile bases.

Dow's deep research in bromine chemistry has aerospace importance in fire extinguishing and fire prevention. Dibromodifluoromethane, a Dow material unique in its low toxicity, is used to combat inflight fires. Bromochloromethane is mixed with detergent and sprayed on runways in a thick foam to reduce friction and prevent fires.

Dow additives prevent icing in jet aircraft fuels. For solid propellants still under development,

About half of the business developed by Dow's newest operation in metals—Precision Fabrication Services—at Denver, Colorado, is in the aerospace field. Parts, such as these from solid blocks of titanium, are made by PFS using numerically controlled machining.

Dow is producing polymers that increase both the burning rate and combustion efficiency.

No matter how soon an American walks on the moon, it will be several years after the lunar arrival of a product made by Dow. The Ranger 4 vehicle, which impacted on the moon 64 hours after it was launched April 23, 1962, included almost 100 components fabricated in magnesium.

Aluminum produced by Dow is playing a larger role than ever in aerospace work. Approximately three miles of aluminum pipe extruded by Dow has been installed at Merritt Island, Florida. It carries nitrogen gas to the launch pad at Complex 39 where Apollo spacecrafts will be lifted into space via Saturn vehicles.

Dow magnesium made the Early Bird communications satellite lighter. It's shown with 480 phones, the number it can handle simultaneously along with TV, facsimile and teletype messages. Magnesium is truly a space-age metal going into Agena, Telstar, Gemini, Titan, Polaris, Jupiter, Scout, Courier, Echo, Mariner and others destined for outer space.